1 Introduction to OOAD

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1.4 What is an Object?
1.5 Objects and Classes
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1.1 Schedule

- Day 1: OO Concepts, UML
- Day 2: Principles of OO Class Design
- Day 3: Large Applications (Package Design)
- Day 4: OO Analysis and Project Management
- Day 5: Overflow Topics and Discussion
1.2 What is OO?

- A method to design and build large programs with a long lifetime
  - e.g. > 50k loc C++ with O(a) lifetime
  - Blueprints of systems before coding
  - Development process
  - Maintainance and modifications
  - Control of dependencies
  - Separation into components
1.2 Just another paradigm?

- Object-orientation is closer to the way problems appear in life (physical and non-physical)
- These problems generally don’t come formulated in a procedural manner
- We think in terms of ”objects” or concepts and relations between those concepts
- Modelling is simplified with OO because we have objects and relations
1.2 SA/SD and OO

Top-down hierarchies of function calls and dependencies

Bottom-up hierarchy of dependencies
1.2 Common Prejudices

- **OO was used earlier without OO languages**
  - Doubtful. A well made procedural program may deal with some of the OO issues but not with all
  - OO without language support is at least awkward and dangerous if not quite irresponsible

- **It is just common sense and good practices**
  - It is much more than that, it provides formal methods, techniques and tools to control design, development and maintainance
1.3 Why OOAD?

- Software complexity rises exponentially:
  - 70’s O(10) kloc (e.g. JADE)
  - 80’s O(100) kloc (e.g. OPAL)
  - 90’s O(1) Mloc (e.g. BaBar)

- Need for tools to deal with complexity ➔
  OOAD provides these tools
1.3 Why OOAD in Physics?

- **Physics is about modelling the world:**
  - Objects interact with each other according to laws of nature: particles/fields, atoms, molecules and electrons, liquids, solid states

- **OOAD creates models by defining objects and their rules of interaction:**
  - This way of thinking about software is well adapted and quite natural to physicists

- **OOAD is a software engineering practice:**
  - manage large projects professionally
1.4 What is an Object?

An object has:
- interface
- behaviour
- identity
- state

Interface:
- Method signatures

Behaviour:
- Algorithms in methods

Identity:
- Address or instance ID

State:
- Internal variables
1.4 Object Interface

Create an object (constructors)
- from nothing (default)
- from another object (copy)
- from 3 coordinates

The object interface is given by its *member functions* described by the objects class

A dot product
A cross product
Magnitude

And possibly many other member functions

ThreeVector

+ThreeVector()
+ThreeVector(const ThreeVector &)
+ThreeVector(double, double, double)
+dot(const ThreeVector &): double
+cross(const ThreeVector &): ThreeVector
+mag(): double
1.4 Object Identity

... 

ThreeVector a;
ThreeVector b(1.0,2.0,3.0);

... 

ThreeVector c(a);
ThreeVector d = a+b;

... 

ThreeVector* e = new ThreeVector();
ThreeVector* f = &a;
ThreeVector& g = a;

... 

double md = d.mag();
double mf = f->mag();
double mg = g.mag();

... 

There can be many objects (instances) of a given class:

Symbolically:
a \ne b \ne c \ne d \ne e
but f = g = a

Pointer (*): Address of memory where object is stored; can be changed to point to another object

Reference (&): Different name for identical object
1.4 Object State

The internal state of an object is given by its data members.

Different objects have:
- different identity
- different state
- possibly different behaviour
- but always the same interface

Objects of the same class can share data (explicitly declared class variables):
- e.g. static data members in C++

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<table>
<thead>
<tr>
<th>p: ThreeVector</th>
</tr>
</thead>
<tbody>
<tr>
<td>-x: double = 2.356</td>
</tr>
<tr>
<td>-y: double = 19.45</td>
</tr>
<tr>
<td>-z: double = -5.284</td>
</tr>
<tr>
<td>-n: int = 5</td>
</tr>
<tr>
<td>+ThreeVector()</td>
</tr>
<tr>
<td>+ThreeVector(:const ThreeVector &amp;)</td>
</tr>
<tr>
<td>+ThreeVector(:double,:double,:double)</td>
</tr>
<tr>
<td>+dot(:const ThreeVector &amp;): double</td>
</tr>
<tr>
<td>+cross(:const ThreeVector &amp;): ThreeVector</td>
</tr>
<tr>
<td>+mag(): double</td>
</tr>
</tbody>
</table>
1.4 Object Behaviour

class ThreeVector {
    public:
        ThreeVector() { x=0; y=0; z=0; };
        ... 
        double dot( const ThreeVector & ) const;
        ThreeVector cross( const ThreeVector & ) const;
        double mag() const;
        ...
    private:
        double x, y, z;
}
1.4 Object Interactions

Objects interact through their interfaces only

Objects manipulate their own data but get access to other objects' data through interfaces.

Most basic: get() / set( ... ) member functions, but usually better to provide "value added services", e.g.
- fetch data from storage
- perform an algorithm

```cpp
A::needXandY(B b) {
  ...
  float myY = b.getY();
  ...
}
```
1.4 Objects keep data hidden

Stop others from depending on the data model
Provide algorithms which use the data instead
Can give direct and efficient access to data in controlled way
\[\Rightarrow\] pass (const) references or pointers
Can change member data layout without affecting other objects
Can replace member data e.g. by database lookup
1.4 Object Construction/Destruction

Construction:
Create object at run-time
Initialise variables
Allocate resources
→ Constructor member functions

Destruction:
Destroy object at run-time
Deallocate (free) resources
→ Destructor member function
1.4 Objects Summary

- **Objects have interface, behaviour, identity, state**
- **Objects collaborate**
  - send messages to each other
  - use each other to obtain results
  - provide data and ”value-added services”
- **Objects control access to their data**
  - data private
  - access through interface
1.5 Objects and Classes

- Objects are described by classes
  - blueprint for construction of objects
  - OO program code resides in classes
- Objects have type specified by their class
- Classes can inherit from each other
  - implies special relation between corresponding objects
- Object interfaces can be separated from object behaviour and state
1.5 Classes describe Objects

- **Class code completely specifies an object**
  - interface (member function signature)
  - behaviour (member function code)
  - inheritance and friendship relations
- **Object creation and state changes at run-time**
- **In OO programs most code resides in the class member functions**
  - objects collaborate to perform a task
1.5 Classes = Types

- **Class** is a new programmer-defined data type
- **Objects have type**
  - extension of bool, int, etc
  - e.g. type complex doesn’t exist in C/C++, but can construct in C++ data type complex using a class
- **ThreeVector** is a new data type
  - combines 3 floats/doubles with interface and behaviour
  - can define operators +, −, * , / etc.
1.5 Class Inheritance

- Objects are described by classes, i.e. code
- Classes can build upon other classes
  - reuse (include) an already existing class to define a new class
  - the new class can add new member functions and member data
  - the new class can replace (overload) inherited member functions
  - interface of new class must be compatible
1.5 Classes Summary

- Classes are blueprints for construction of objects
- Class = data type of corresponding objects
- Classes can inherit (build upon) other classes
1.6 Separation of Interfaces

- Interface described by class A with no (or little) behaviour
  - member function signatures
  - perhaps not possible to create objects of type A
- Now different (sub-) classes (B, C, D) can inherit from A and provide different behaviour
  - can create objects of type B, C or D with identical interfaces but different behaviour
  - code written using class A can use objects of type B, C or D
1.6 Object Polymorphism

Objects of type A are actually of type B, C or D
Objects of type A can take many forms, they are polymorphic
Code written in terms of A will not notice the difference
but will produce different results
Can separate generic algorithms from specialisations
Avoids explicit decisions in algorithms (if/then/else or case)
1.6 Interface Abstraction

- The common interface of a group of objects is an abstraction (abstract class, interface class)
  - find commonality between related objects
  - express commonality formally using interfaces
- Clients (other objects) depend on the abstract interface, not details of individual objects
  - Polymorphic objects can be substituted
- Need abstract arguments and return values
  - or clients depend on details again
1.6 Mechanics of separated interfaces

Virtual function table with function pointers in statically (strongly) typed languages, e.g. C++, Java

A
1 doSomething 0x3BA5 0x8BF1
2 display 0x0BF3 0x2CD5
3 cleanup 0x6437 0x7883

B::doSomething C::doSomething
B::display C::display
B::cleanup C::cleanup

Fast and efficient!

Lookup by name in hash-tables in dynamically typed languages (Perl, Python, Smalltalk)
1.6 Separated Interfaces Summary

- Interface can be separated from object
  - Abstract (interface) classes
- Express commonality between related objects
  - Abstraction is the key
- Clients depend on abstractions (interfaces), not on specific object details
- Mechanism is simple, fast and efficient
- Polymorphic objects can replace code branches
1.7 Inheritance SA/SD vs OO

SA/SD:
Inherit for functionality

We need some function, it exists in class A → inherit from A in B and add some more functionality

OO:
Inherit for interface

There are some common properties between several objects → define a common interface and make the objects inherit from this interface
1.7 Tools for OOAD

• A (graphical) modelling language
  – allows to describe systems in terms of classes, objects and their interactions before coding

• A programming language
  – Classes (data+functions) and data hiding
  – Interface separation (class inheritance and member function overload)

• Not required for OOAD (but useful)
  – templates, lots of convenient operators